# DAΦNE Setup and Run for the SIDDHARTA-2 kaonic-Ne data taking

*Catia Milardi*
on behalf of the DAΦNE Team

*65th Scientific Committee Meeting May 4th, 2023*

# DAΦNE Team

C. Milardi, D. Alesini, M. Behtouei, S. Bilanishvili, S. Bini, M. Boscolo, B. Buonomo, S. Cantarella, F. Cardelli, A. Ciarma, A. De Santis, E. Di Pasquale, D. Di Giovenale, C. Di Giulio, G. Di Pirro, A. Drago, A. D'Uffizi, *O. Etisken*, L. Foggetta, G. Franzini, A. Gallo, R. Gargana, S. Incremona, A. Liedl, A. Michelotti, L. Pellegrino, L. Piersanti, R. Ricci, U. Rotundo, *S. Spampinati*, A. Stecchi, A. Stella, A. Vannozzi, M. Zobov

P. Raimondi, CERN, and SLAC (visiting LNF in April)

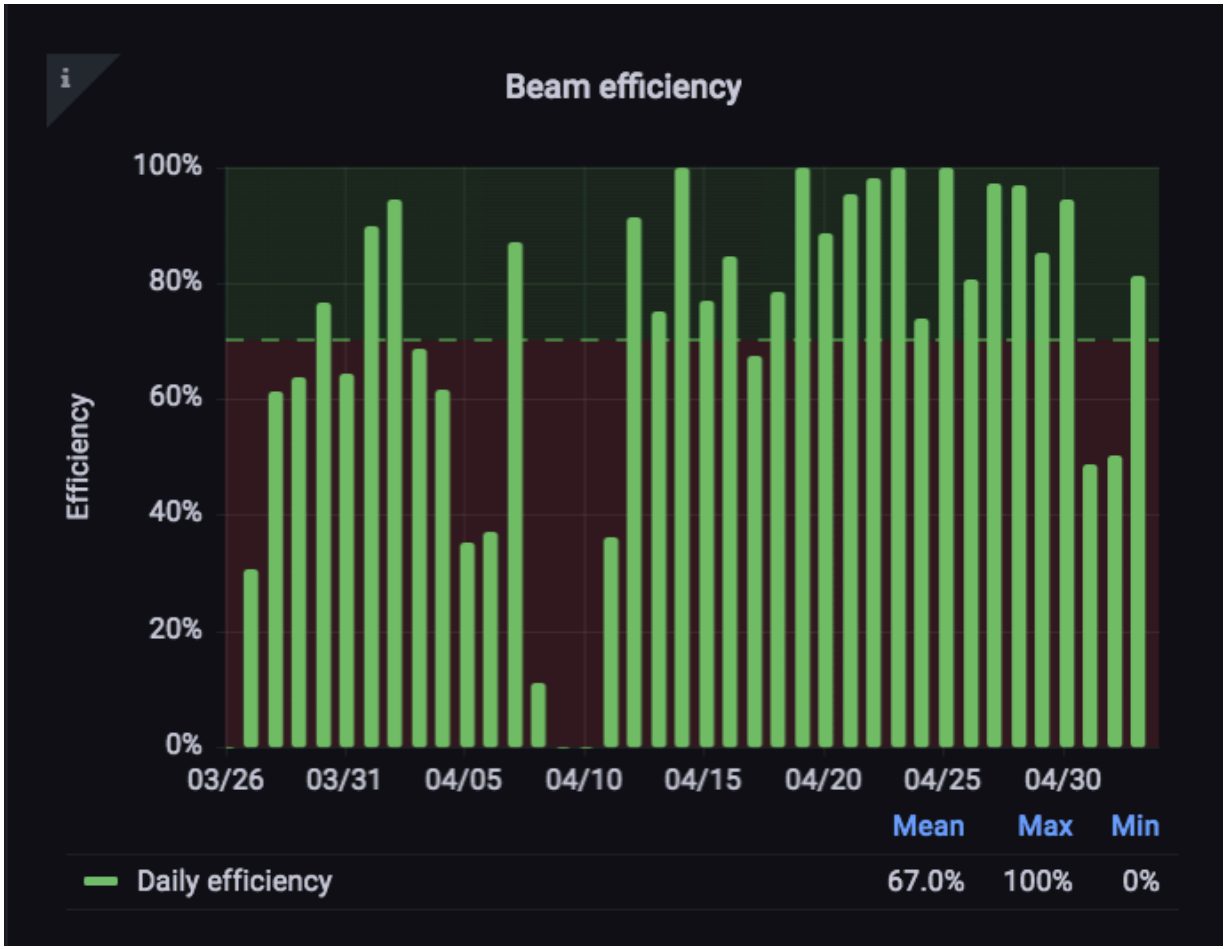
# Run Overview

*DAΦNE operations for SIDDHARTA-2 restarted by mid March after 8 months shutdown, that was used to recover full LINAC operability and to implement some maintenance intervention on the power supplies.*

*The first 10 days of operations have been spent to setup all subsystems, and to fix several faults.*

*Beams were stored for the first time at the end of March*

# Uptime




*At least 35 mA stored in both beams*

# Main Downtime Sources

*Power Supplies*

- *IGbT drive board of the DanFisik PS family*
- *PS of Accumulator magnets*

*Cooling Systems*

- *faulty pump replaced*

*LINAC*

- *electronic equipment of FR plant A and positron converter*

*Control System*

- *virtualization process*
- *CS network which is under computing center control*

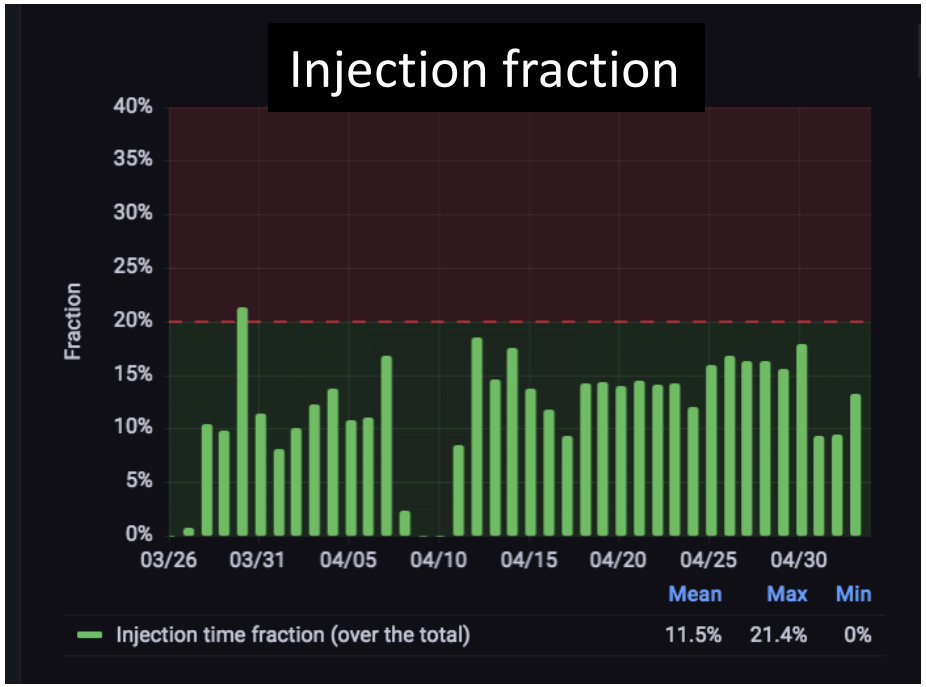
*Power network failures*

# Injection

Injection profited from the recovered stability and reproducibility of the injector system.

Injection efficiency  is now in the range of 70% ÷ 80% for both beams,
transport efficiency along the transfer lines is close to 100%.

These performances have significantly contributed to store high beam currents and to properly setup all the subsystems responsible for beam stability.

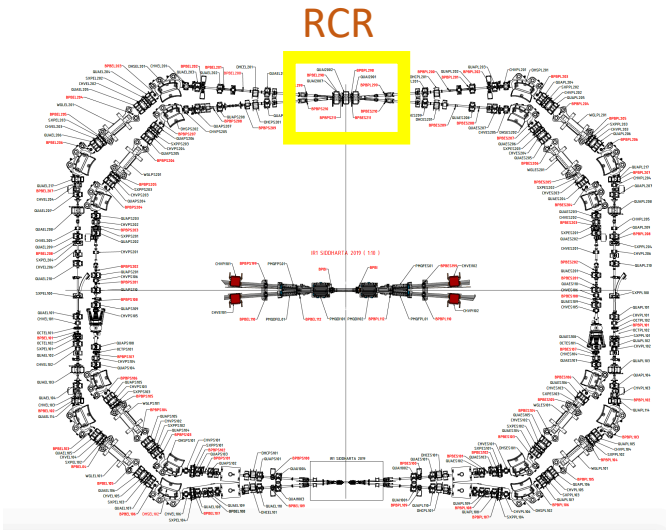


# Linear and Non-Linear Optics

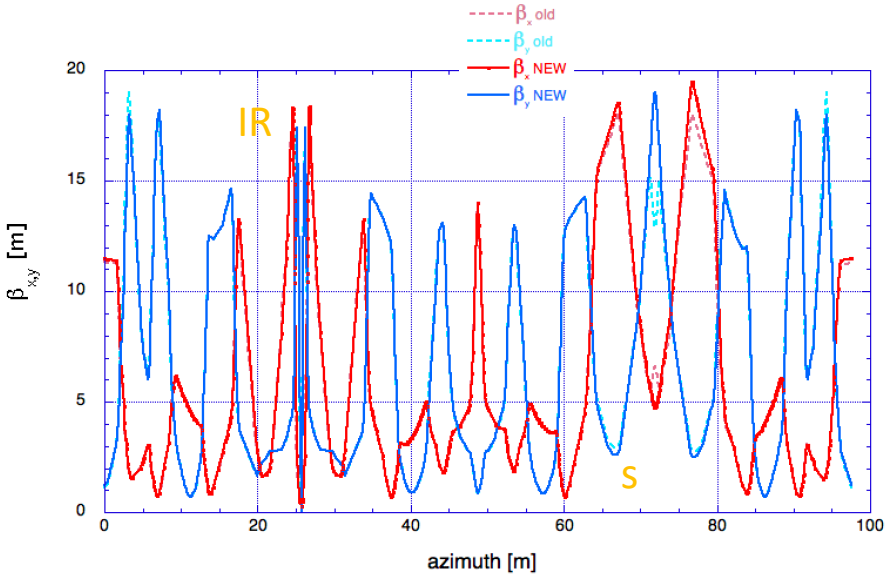
# Main Rings Optics

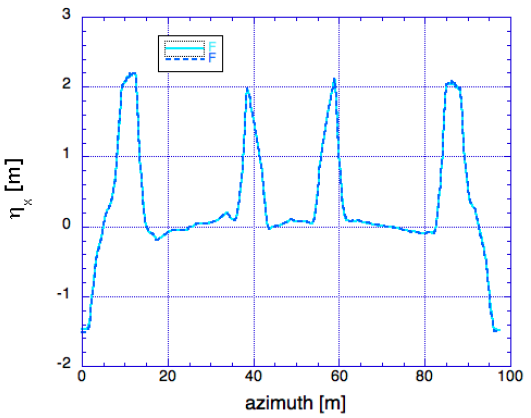
New Crab-Waist ring optics

- symplified focusing structure in the RCR,
- 2 QUADs where beams pass off-axis are switched off, thus eliminating spurious component in the QUADs magnetic field,
- Same optics parameters in the IR.




New optics improves closed orbit correction allowing to reduce the total strength of the used steering magnets, thus also contributing to minimize vertical dispersion



# Non-linear Optics

***Sextupole magnets***:

were set to correct chromaticity to zero,

Their alignment has been checked by beam-based measurements, in a few cases small closed orbit bumps have been applied to restore optimal alignment conditions,

one of the Crab-Waist sextupole in MRp required 1 mm mechanical alignment in the horizontal plane,

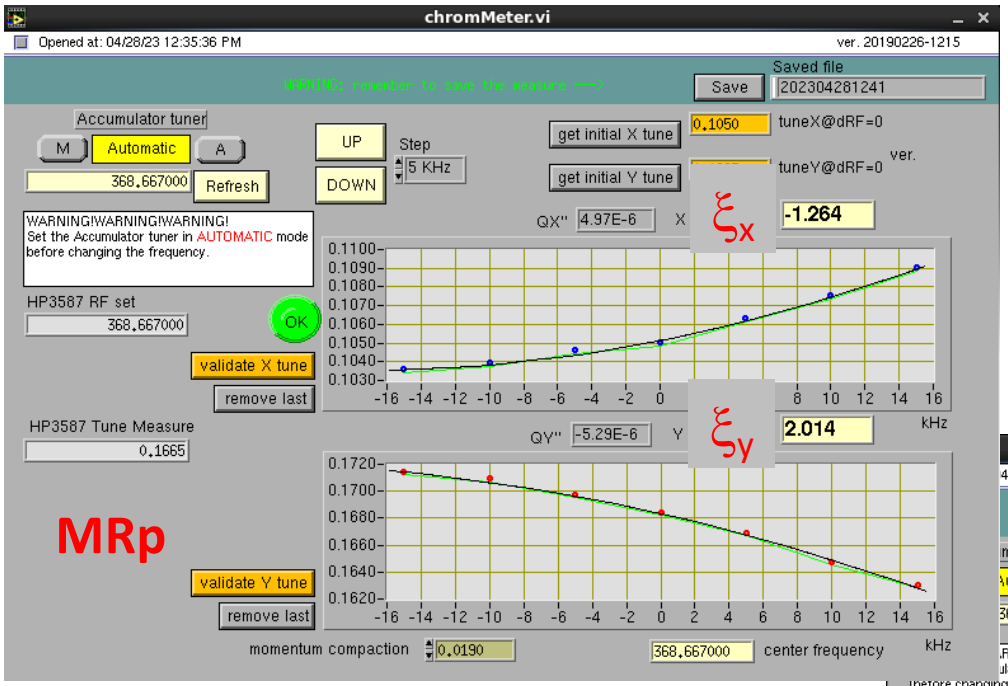
then they have individually tuned in order to reduce the background shower on the detector and to improve the ring acceptance in injection,

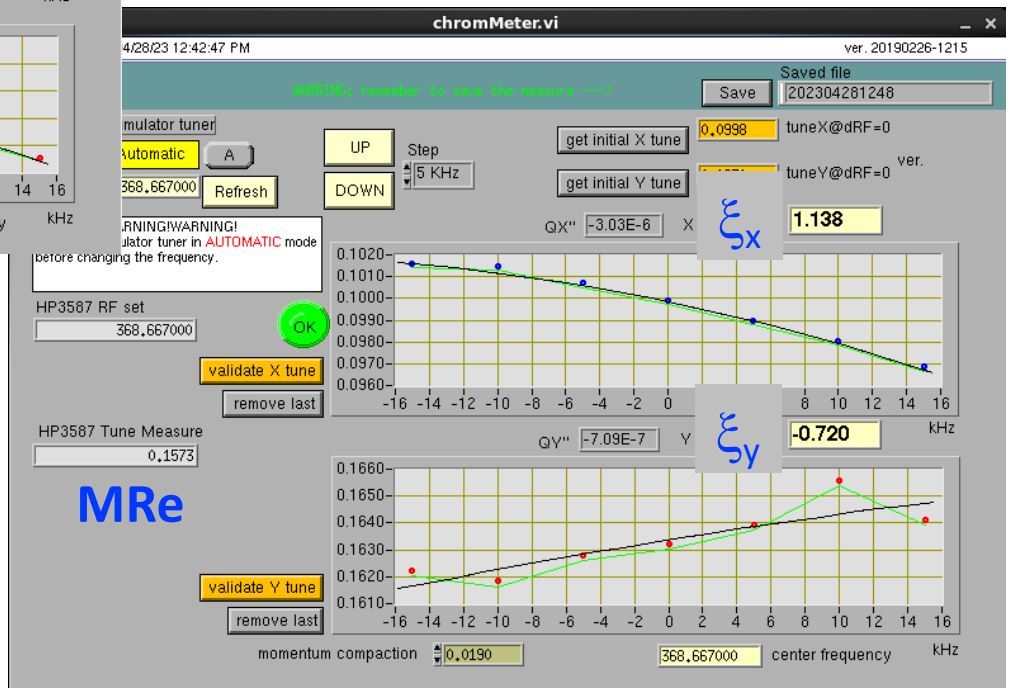
At some point this iterative procedure required revising vertical dispersion correction, this was done by applying vertical closed orbit
bumps at some of the modified magnets.

***Crab-Waist Sextupoles*** have been progressively switched on, presently they are set at approximately 70% of their optimal strength.

***Octupole magnets*** were used in the MRp only where they contribute to mitigate e-clou induced effects by introducing Landau damping and to reduce background

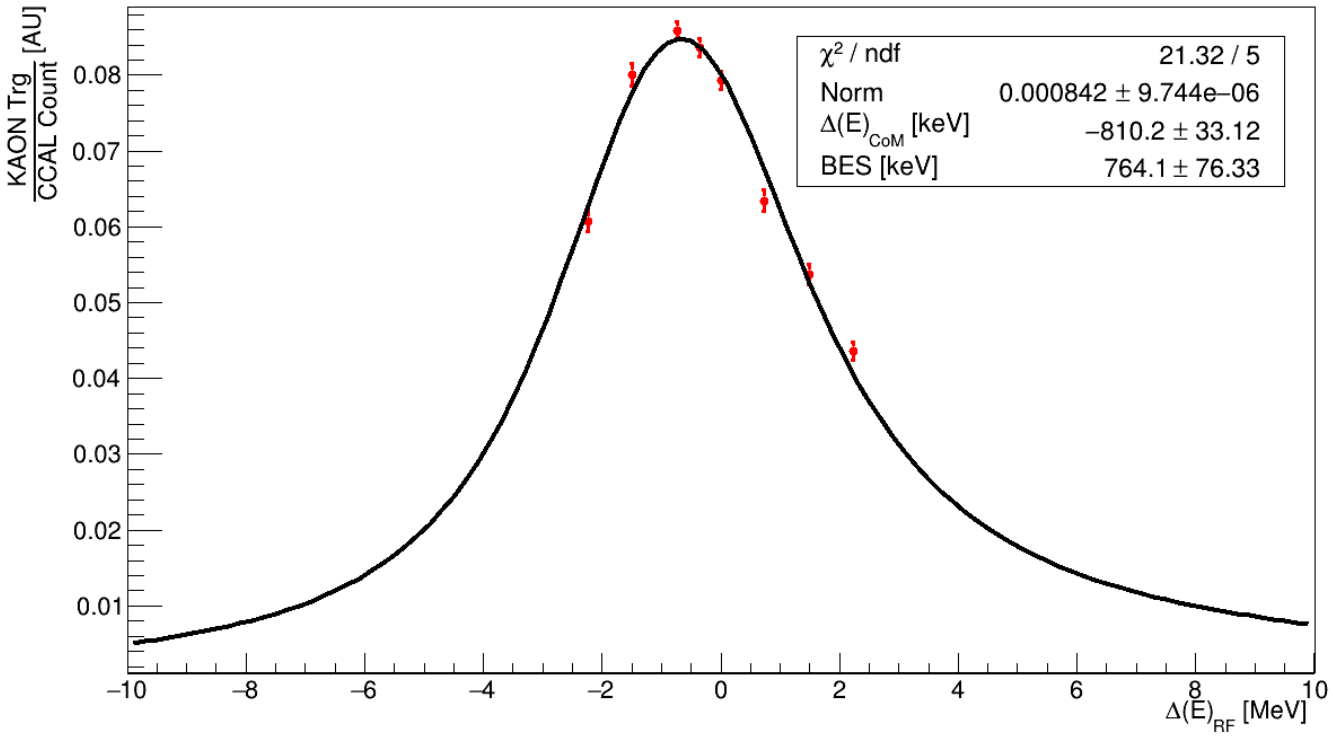
# Chromaticity Measurements



# Energy Scan

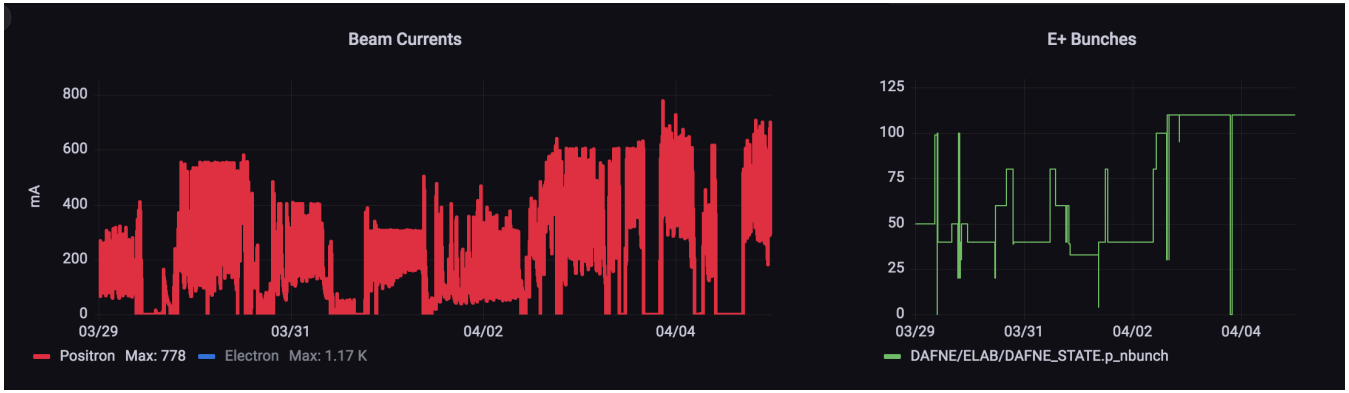
$\Delta E_{CM}$ = - 760 keV ⟶ 7% gain in terms of charged kaon yield




Energy scan as a function of the absolute energy deviation w.r.t. the starting point of the scan, the fitting function includes radiative corrections and the beam energy spread is left as free parameter.

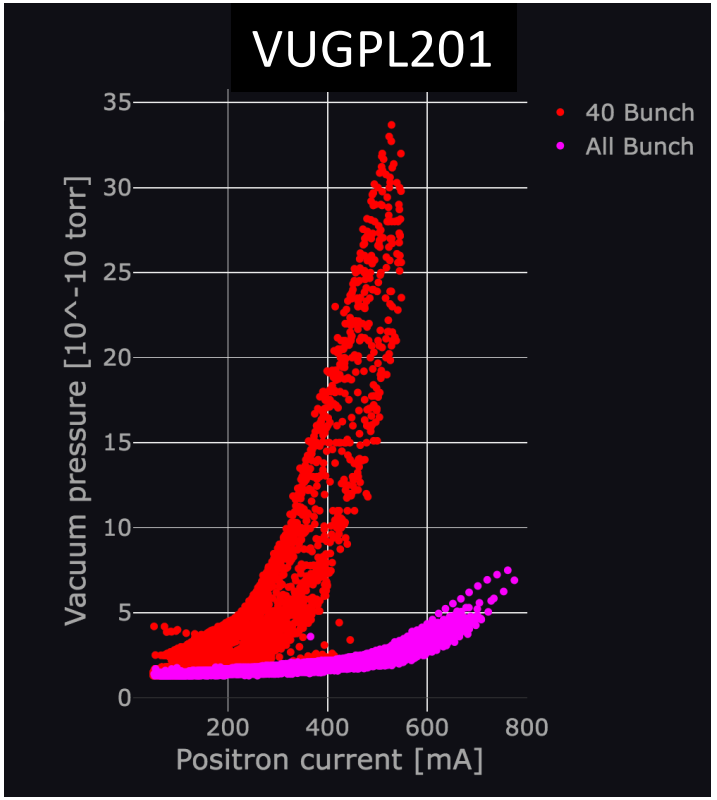
# Beam Dynamics
# Vacuum

# Scrubbing Dedicated Runs

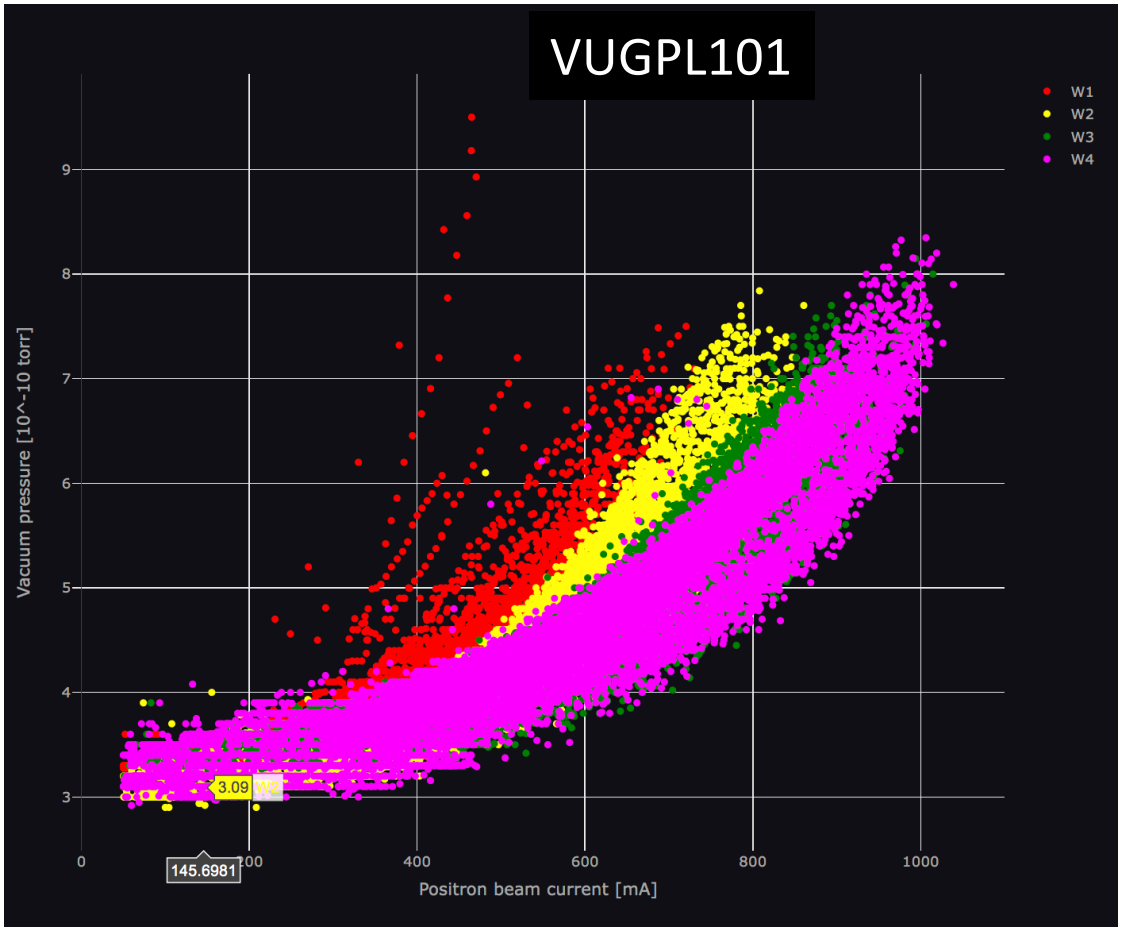



In the first stage of the operations dedicated beam **conditioning**, and beam ***scrubbing runs.***

***Scrubbing*** carried out using 40 bunches pattern with 2 empty buckets spacing and switching off solenoids to enhance e-cloud activity.



# Scrubbing during Operations




110 contigous bunches

Pressure rise at VUGPL101, different colors represents values measured in different weeks

# Beam Dynamics
# RF and Feedback Systems

# RF and Feedback Systems

Each DAΦNE ring is equipped with **one RF** and **three independent FBK** systems dedicated to mitigate longitudinal, horizontal, and vertical instabilities.

All major components of RF and FBK systems were **checked**, damaged amplifier in the low-level RF feedback chassis of the MRe RF, and some minor components such as attenuators and filters installed in the FBK chains were replaced.

The different system operation **setups were tuned**, at first in single beam operation mode and moderate current, then setups were refined in collision and at high current, having special care in avoiding destructive interference among different systems, and between systems and beam-beam interaction.

# RF and Feedback Systems

A harmful interference between longitudinal instabilities and beam-beam interaction was cured by tuning the mode-0 feedback of the RF in MRp, that at high current was in anti-damping.

A rather large difference in the spread of the synchronous phases of the two beams was eliminated by tuning the phase loop of the RF in MRp. This allowed to restore uniform beam current distribution along the $e+$ batch and, in turn, to equalize beam-beam kick for
different bunch pairs.

Sudden electron beam losses occurring above a current threshold in the range 1- 1.1 A have been cured after a meticulous fine-tuning of the low-level RF feedback amplifier and mode-0 feedback.

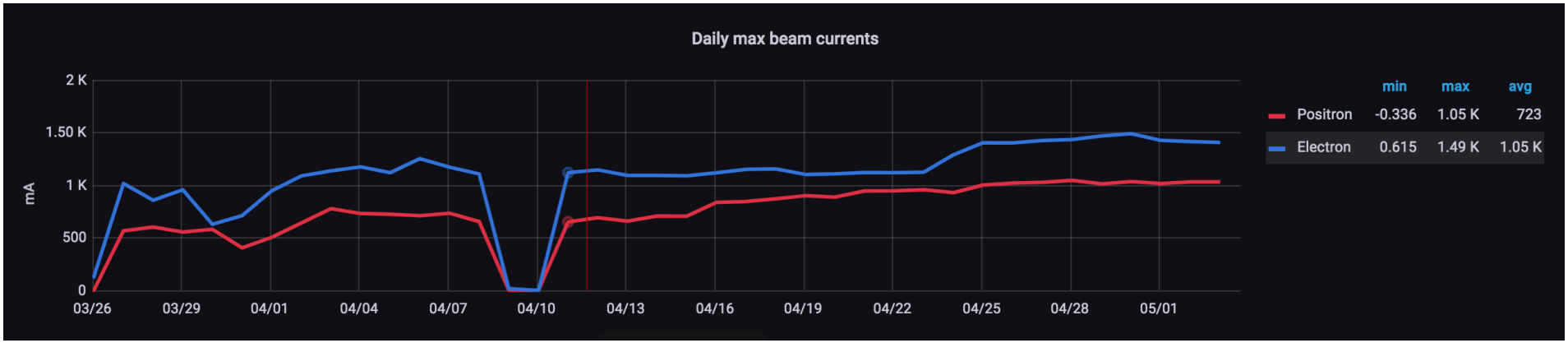
# Beam Currents

Maximum **stable** beam currents stored in collision are now significantly higher if compared with the ones achieved during the previous run in 2022.

$I^+ \simeq 0.6$ A
$I^- \simeq 0.95$ A

→

$I^+ \simeq 1.0$ A
$I^- \simeq 1.47$ A



# Luminosity Measurements

luminosity measurement relies on two devices:

- **CCAL** measures the Bhabha scattering events at small angle, it consists of two identical crystal calorimeters installed in front of each permanent magnet defocusing quadrupoles of the low-$\beta$ in the IR

- **Gamma monitors** are gamma bremsstrahlung proportional counters which are installed on both sides of the IR where the two beam pipes split

These detectors, thanks to the very high rates, can be efficiently used as real-time tools during machine luminosity optimization.

However, they cannot provide a reliable absolute luminosity measurement since CCAL has not yet been properly calibrated, and the gamma monitor is heavily affected by beam losses.

In this context, the only absolute measurement of the collider luminosity is the one provided by the SIDDHARTA-2 detector based on **charged kaon flux measurement**.

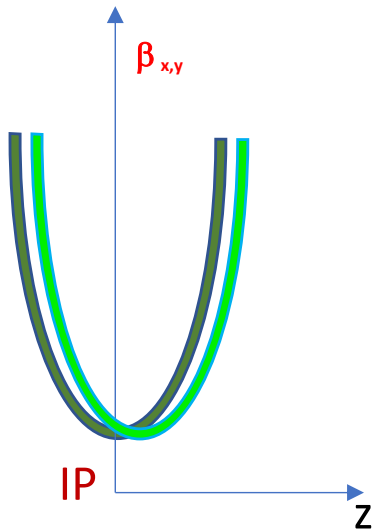
# Luminosity Optimization

Optimal luminosity conditions have been attained by:

- scanning one beam through the other at the IP using:
  - Position and angle closed bumps in the transverse plane,
  - moving the phase of one of the two beam RF cavity to perform longitudinal overlap.

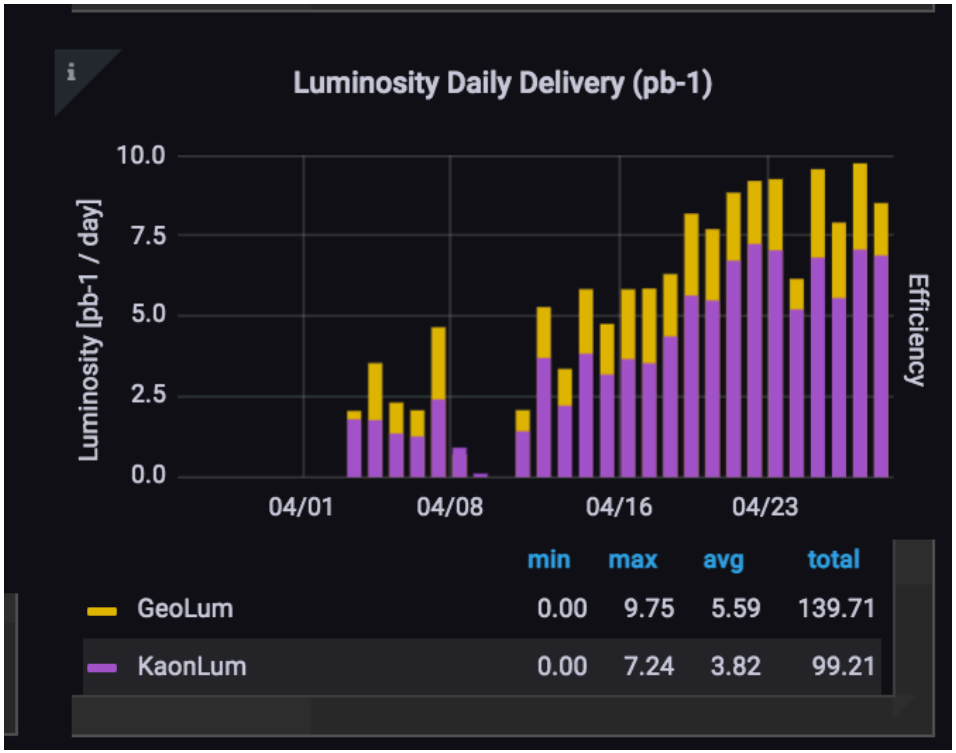
- moving the waist of each beam using orthogonal $\alpha^*_{x,y}$ closed bumps, **waist overlap gave ~ 15% increase in terms of luminosity**.

All the bumps for luminosity optimization in the transverse plane have been computed by using the ring optics model.

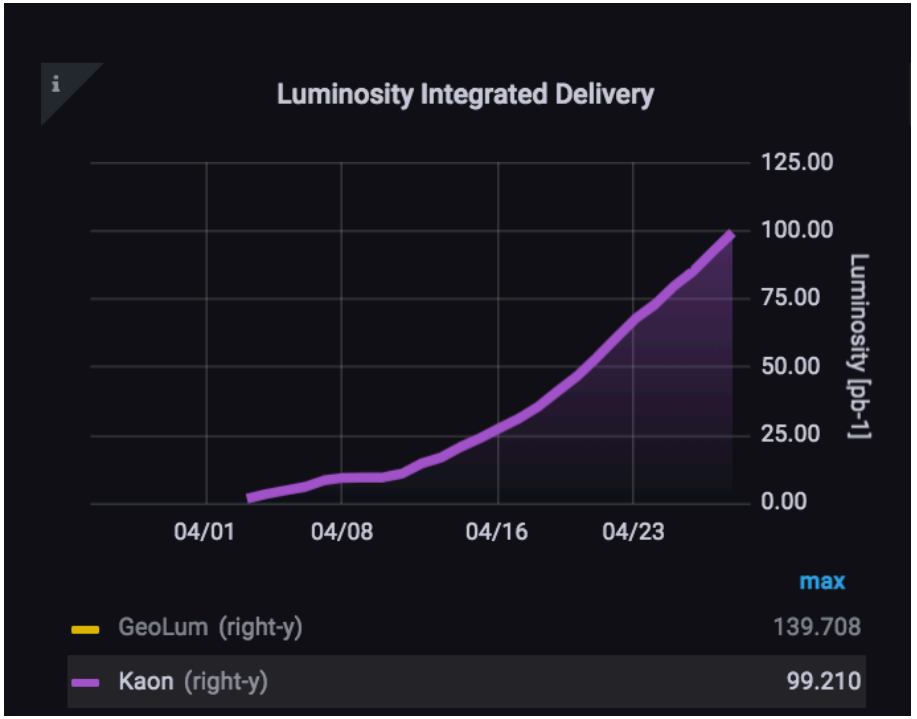


# Acquired Integrated Luminosity

## Daily acquired luminosity

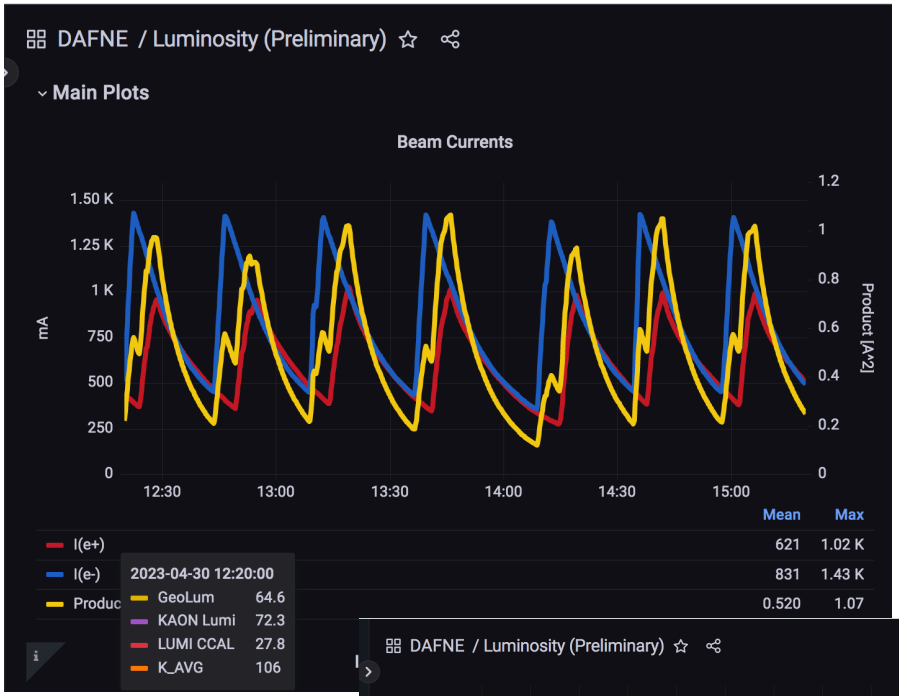



## Total acquired luminosity




*Data stop on past April 28th*

# 3-hour Operations

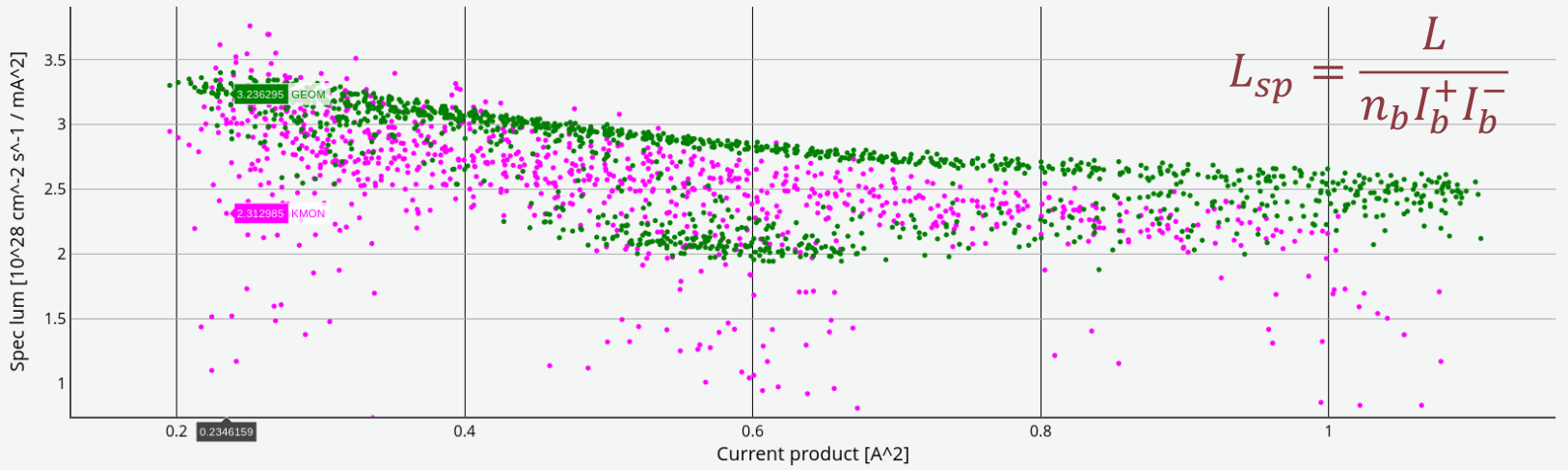




Since April 28th due to the improved background conditions kaon monitors integrates also luminosity delivered during injection.

Integrated luminosity evaluation is more realistic.

# Specific luminosity



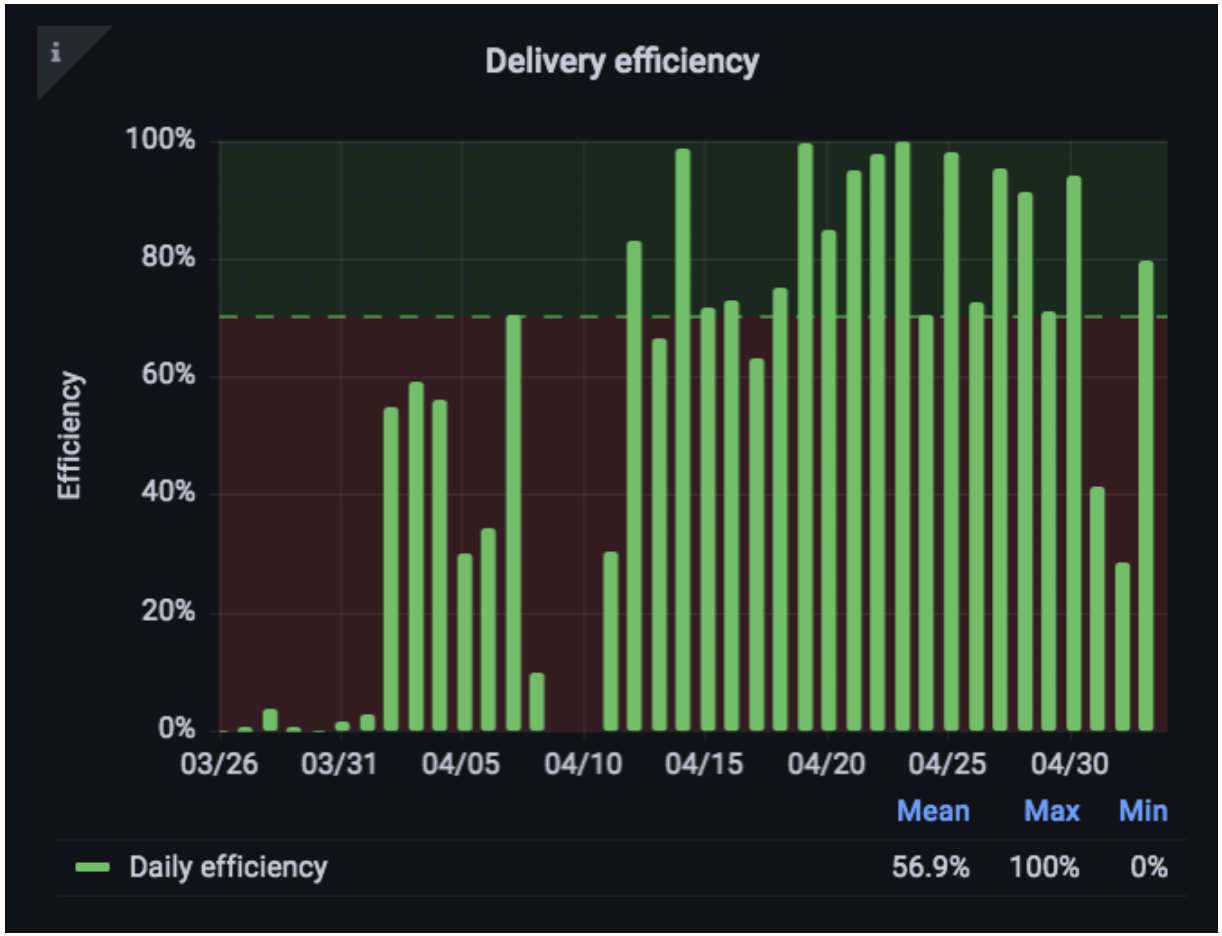

L$sp$ derived by the kaon monitor * and from geometric luminosity *

The two data sets exhibit the same trend, thus indicating that collisions are very well optimized.

The weak dependence of L$sp$ on bunch currents indicates that there is no relevant evidence of beam size blow-up.

***This is one of the main effects of the CW-Sextupoles which keep under control beam-beam resonances***

# Luminosity-delivery Efficiency




*At least **1•10$^{31}$ cm$^{-2}$ s$^{-1}$ luminosity** is delivered*

*Delivering efficency in April was strongly affected by the planned stops required to tune the detector*

# Background Optimization

Background Diagnostics

Initially background optimization process was largely based on the counting rate out of coincidence provided by the CCAL luminometer.
At regime background level is monitored, in real-time, by counters based on Kaon/Mip rate, and Kaon/SDD rate provided by the SIDDHARTA-2 detector.

**Kaon/Mip and Kaon/SDD increased by a factor of 1.4 and 3, respectively.**

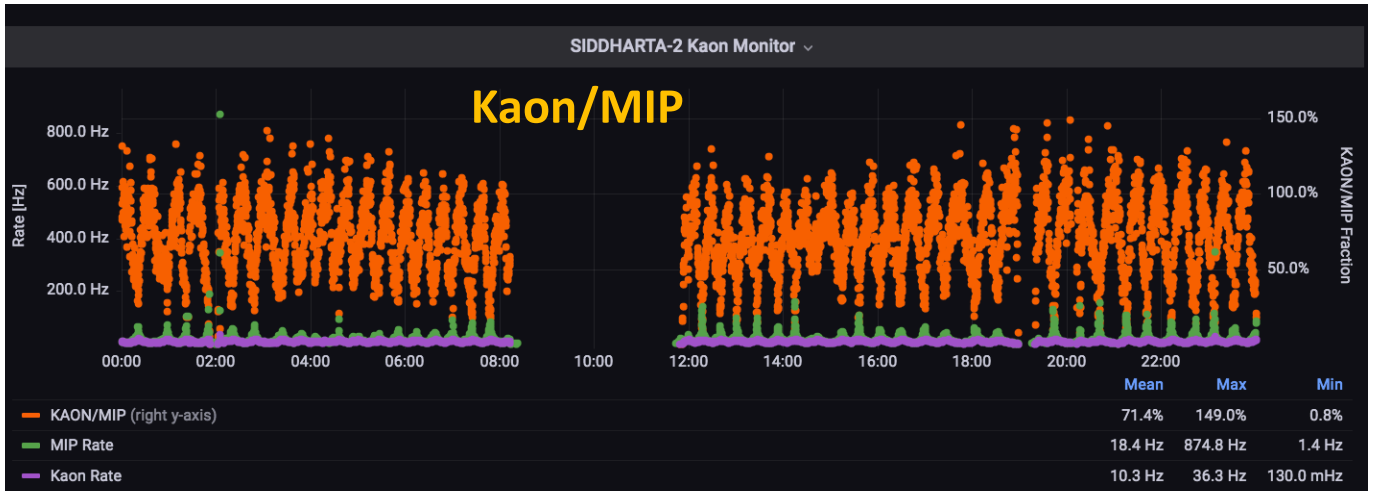
Improvements were due to:

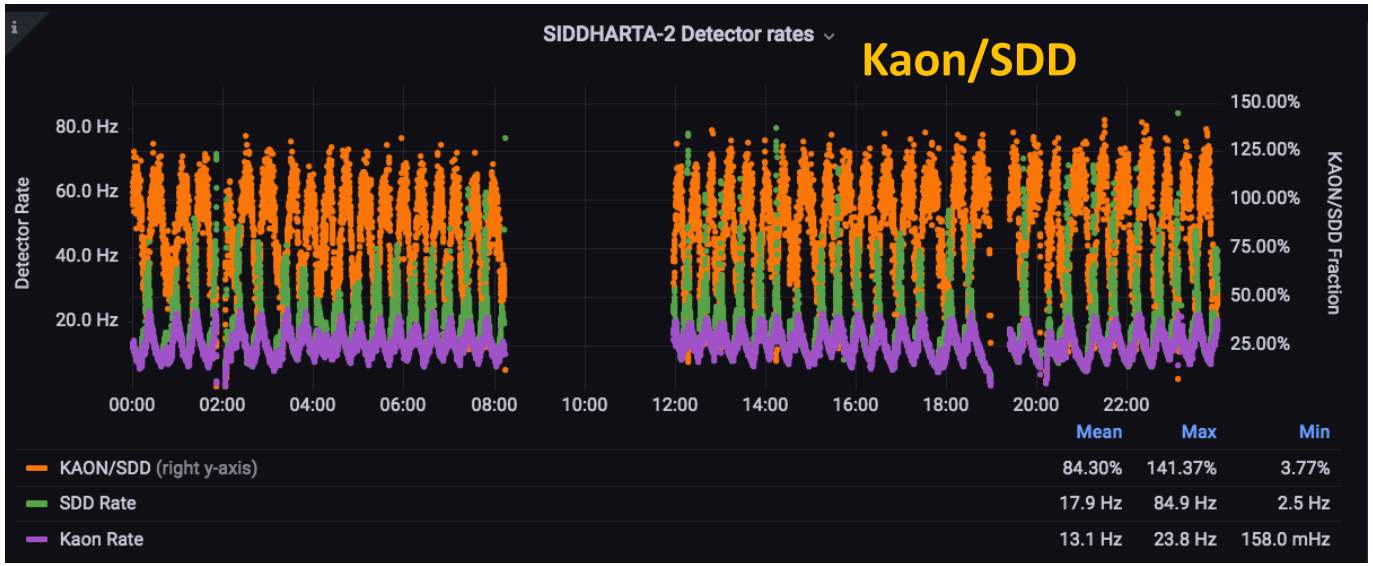
- collimators optimization,
- linear and non-linear optics fine tuning,
- RF cavity and feedback systems configuration, a strong correlation was observed between voltage of the RF cavities and background, reducing the voltage by few 10 of KV a 15% Kaon/MIP rate was measured,
- beam dynamics stability enhancement.

Injection efficiency also played a relevant role especially as far as the background during injection is concerned.

# Background Optimization

**Kaon/Mip and Kaon/SDD increased by a factor of 1.4 and 3, respectively.**



# Conclusion

DAΦNE commissioning has been completed in a very short time.

Collider performances are approaching the optimal achieved in old runs. Instantaneous Luminosity increased by ~ a factor 2.

Background has been considerably reduced and is compatible with an efficient detector data taking. Kaon/Mip and Kaon/SDD increased by a factor of 1.4 and 3, respectively.

A first data sample in excess of 100 $pb^{-1}$ has been delivered to the SIDDHARTA-2 experiment in order to **tune the detector** and realize the **first ever measurement of the kaonic-Ne atom**.

# Acknowledgments

Many thanks to the **Staff of the Accelerator and Technical Divisions**. Their commitment allowed to achieve the present DAΦNE performances.

Special thanks to the ***Operators*** for taking care of the collider and BTF runs  24h a day.

Warm acknowledgment to the SIDDHARTA Team for their fruitful cooperation.

Thanks to **Colleagues of the Scientific Research Division** for helping us to quickly repair several power supply components that broke all at the same time.

# Warning

The DAΦNE Operation Group → **LNF Accelerator Operation Group**

*A very positive evolution indeed*

The **DAΦNE Operation Group** was taking care of activities on the DAΦNE collider, BTF (only 1 line) and, seldom in crucial context, of the SPARCLab activities.

The **LNF Accelerator Operation Group takes care of the** DAΦNE collider, BTF (2 line), and systematically of the SPARCLab activities.

Since last year the **Accelerator Operation Group** lost three highly experienced Technicians, one more will retire by the end of next summer.

Shifts relies on 7 crews of 4 technicians, presently Operation Group has 27 members only …. in few months this number will further reduce.

# Warning

Scientific and Technological activities involving Physicists and Engineers of the AD are growing in number and the people working on DAΦNE collider are becoming less and less

*Scientific and Technical Man power are an issue!*